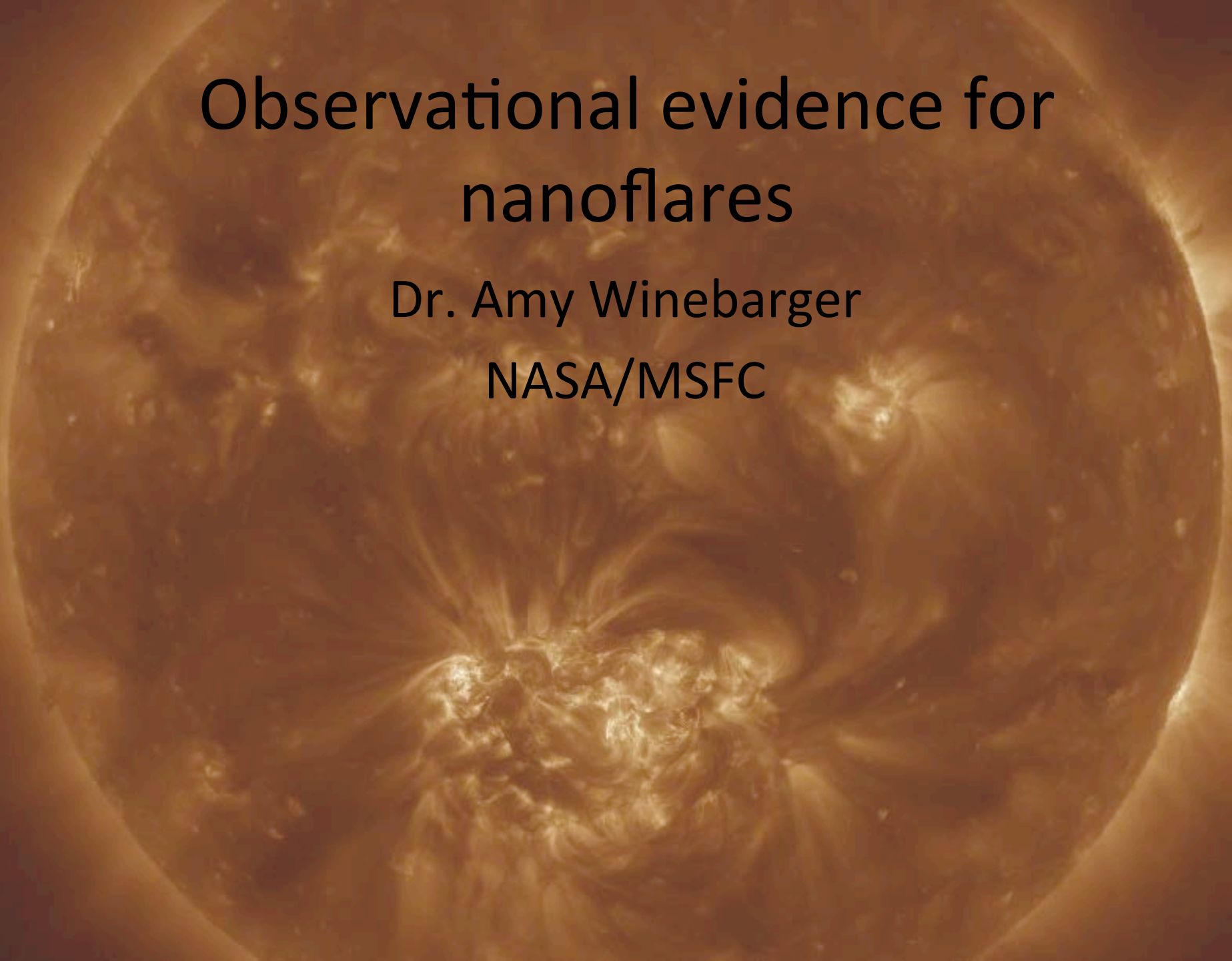


Observational evidence for nanoflares

Dr. Amy Winebarger

NASA/MSFC



What is a **nanoflare**?

(I really don't like this word...)

- Small energy release (Parker's definition)
- Over what spatial scale?
- Over what temporal scale?
- At what frequency?
- At what location?

Observational signatures would be different depending on how these secondary questions are answered.

“Classic nanoflare” due magnetic reconnection

- Small energy release (Parker’s definition)
- Over what spatial scale? \ll Loop length
- Over what temporal scale? Durations \ll cooling time
- At what frequency? Low frequency – Repeat on time scales $>$ cooling time to allow for stress to build back up after reconnection event
- At what location? Equally distributed throughout the corona/chromosphere ?

“Nanoflare” due to wave heating

- Small energy release (Parker’s definition)
- Over what spatial scale? \sim Loop length
- Over what temporal scale? Durations \ll cooling time
- At what frequency? High frequency – Repeat on time scales \ll cooling time
- At what location? More energy released in chromosphere

“Nanoflare” due to wave heating

THE ASTROPHYSICAL JOURNAL, 773:111 (12pp), 2013 August 20

doi:[10.1088/0004-637X/773/2/111](https://doi.org/10.1088/0004-637X/773/2/111)

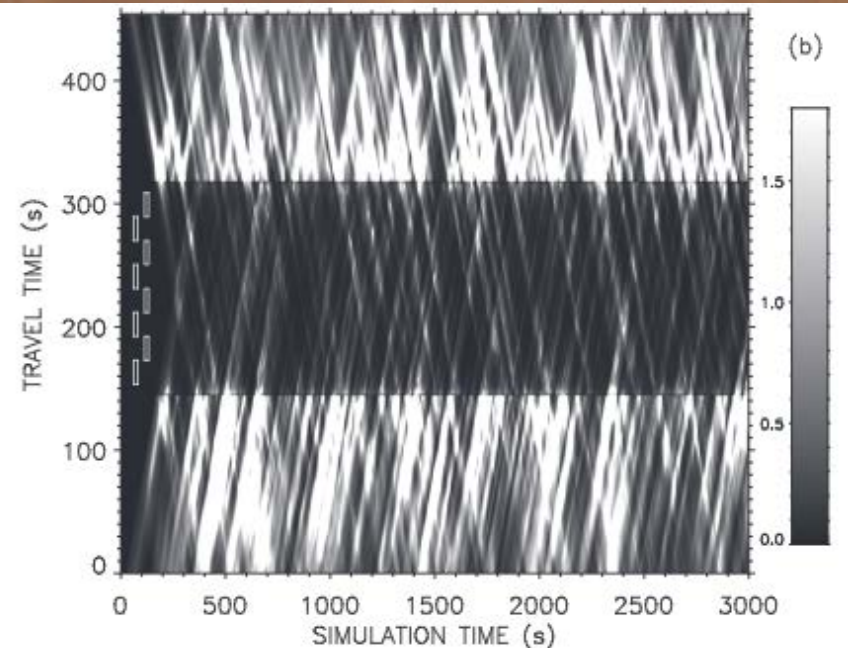
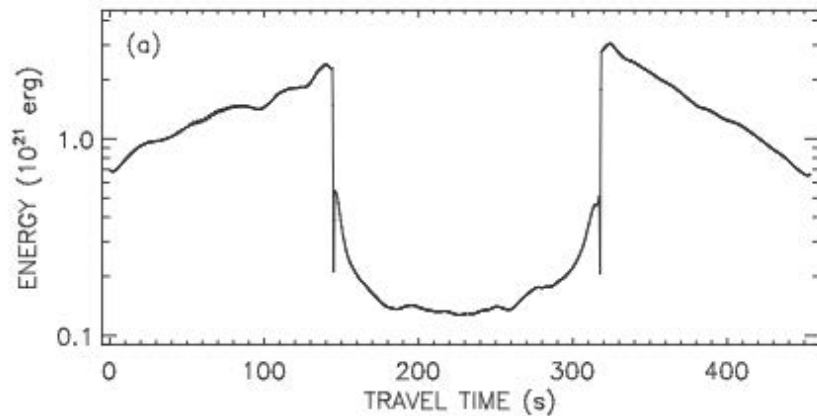
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THE SPATIAL AND TEMPORAL DEPENDENCE OF CORONAL HEATING BY ALFVÉN WAVE TURBULENCE

M. ASGARI-TARGHI, A. A. VAN BALLEGOOIJEN, S. R. CRANMER, AND E. E. DELUCA

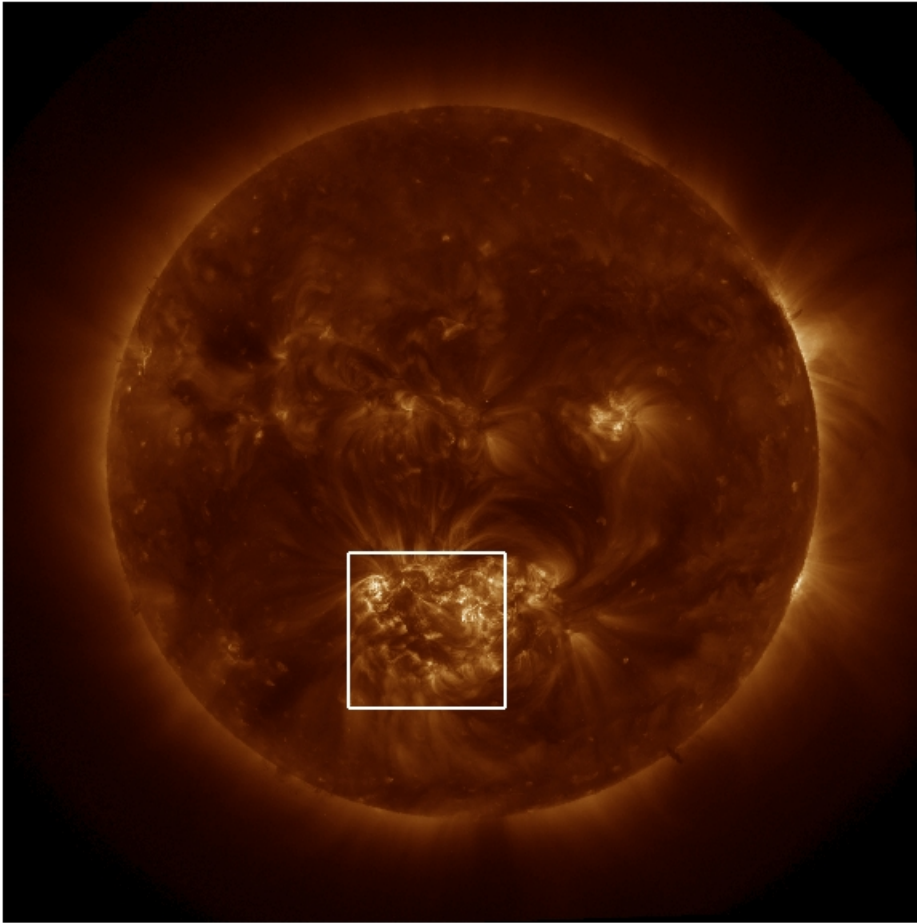
Harvard-Smithsonian Center for Astrophysics, 60 Garden Street MS-15, Cambridge, MA 02138, USA

Received 2013 April 5; accepted 2013 June 25; published 2013 July 31

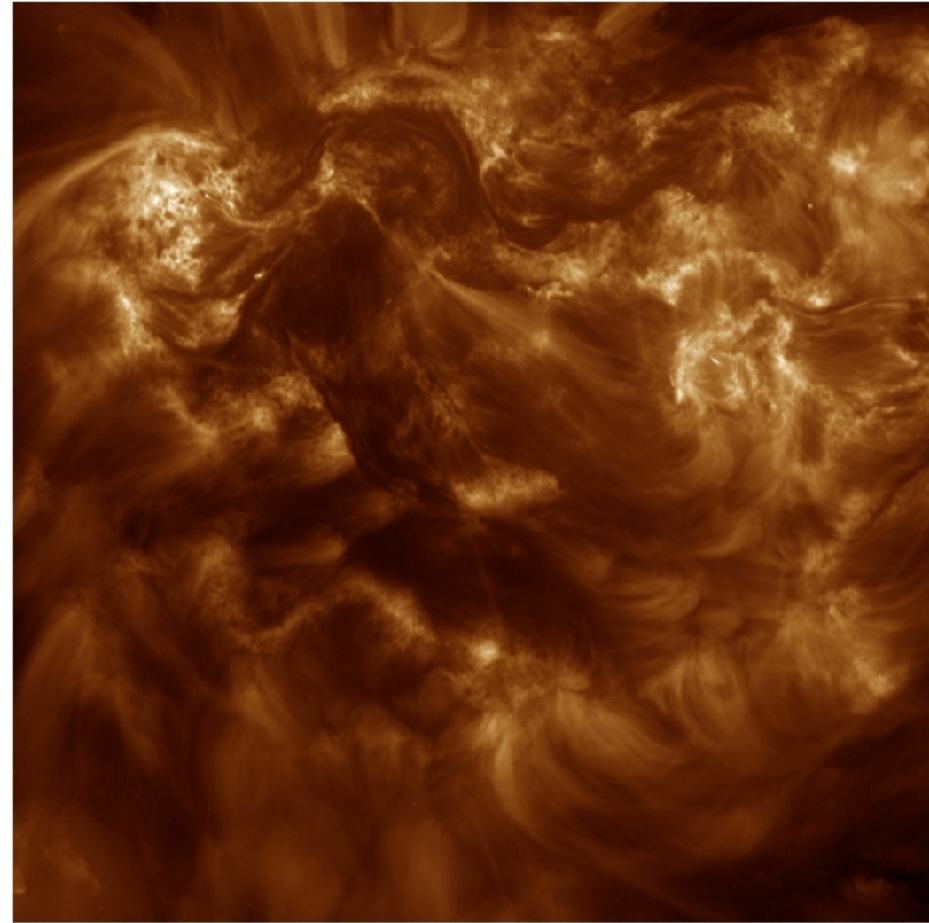


“Classic nanoflare” signatures in Hi-C 1

AIA 193-Å 11-Jul-2012 18:55:07

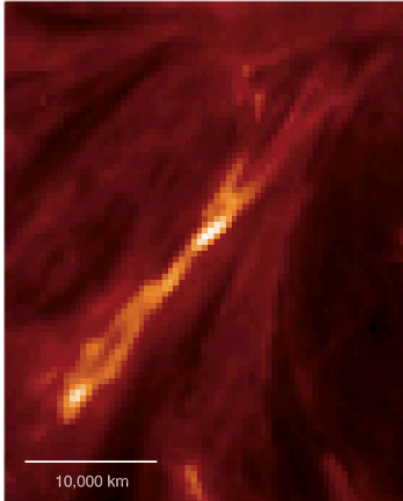


Hi-C Field of View

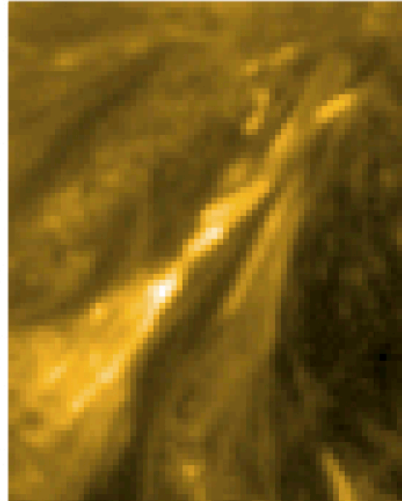


Component Reconnection

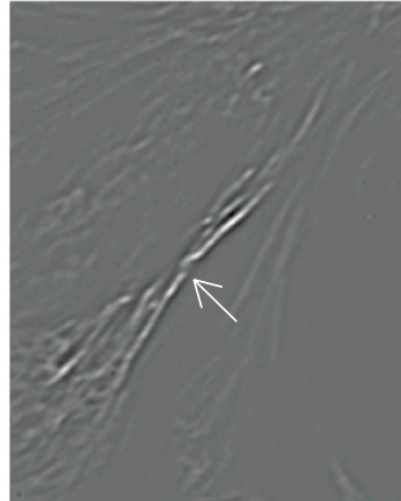
a AIA 304-Å: He II (0.1 MK) 18:55:20



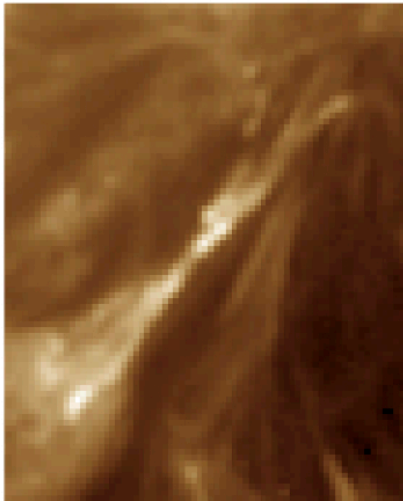
b AIA 171-Å: Fe IX/X (1 MK) 18:55:24



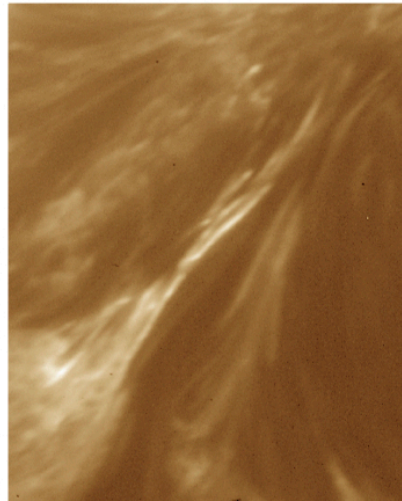
c Hi-C Unsharp Masked Image 18:56:04



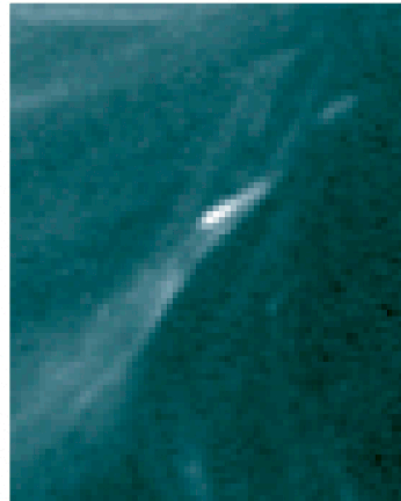
d AIA 193-Å: Fe XII (1.5 MK) 18:55:19



e Hi-C 193-Å: Fe XII (1.5 MK) 18:56:04

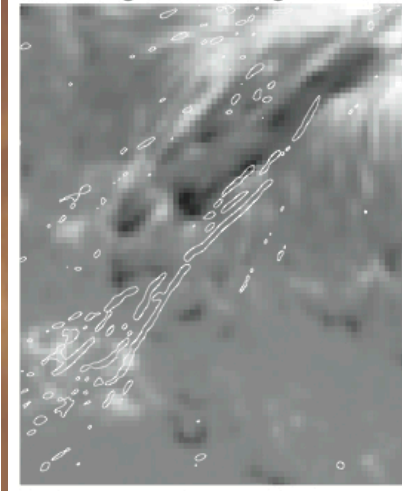


f AIA 94-Å: Fe XVIII (6.3 MK) 18:55:26



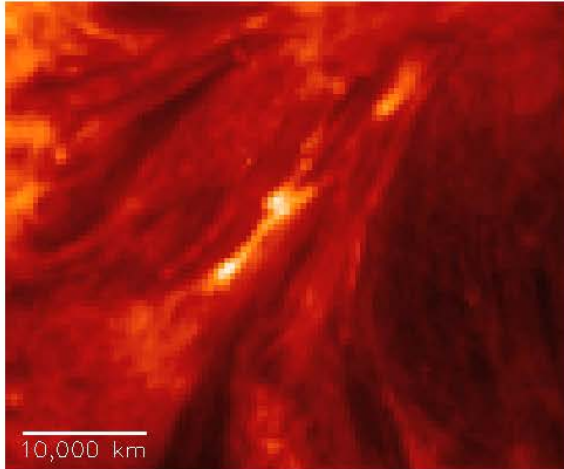
- Magnetic field braiding has been suggested as a energy storage mechanism in the solar corona.
- Hi-C observed braided magnetic field.

b HMI Magnetic Field Region 1

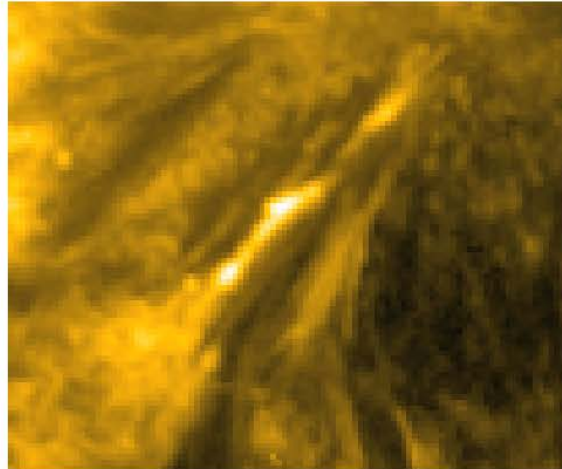


Component Reconnection

a AIA 304-Å 18:52:08



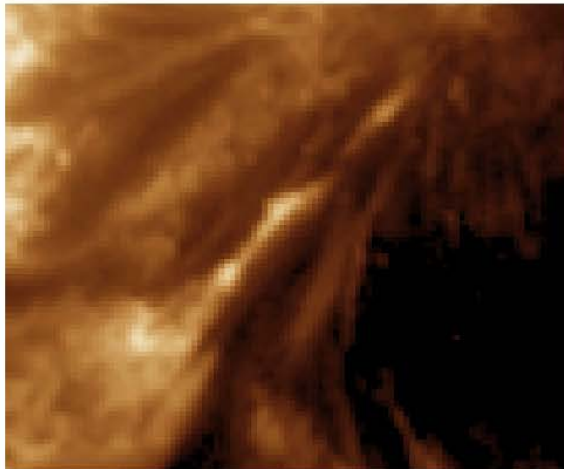
b AIA 171-Å 18:52:12



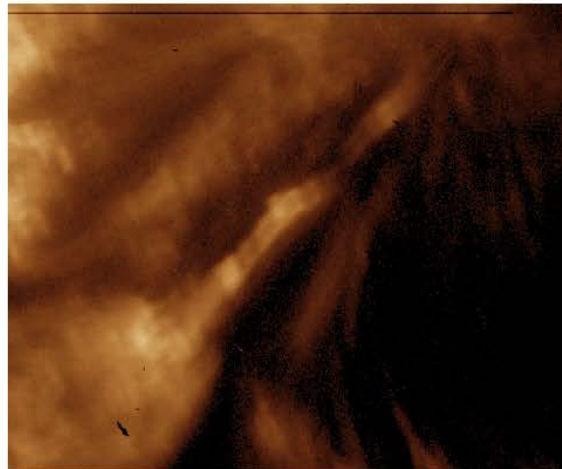
c Hi-C Unsharp Masked Image



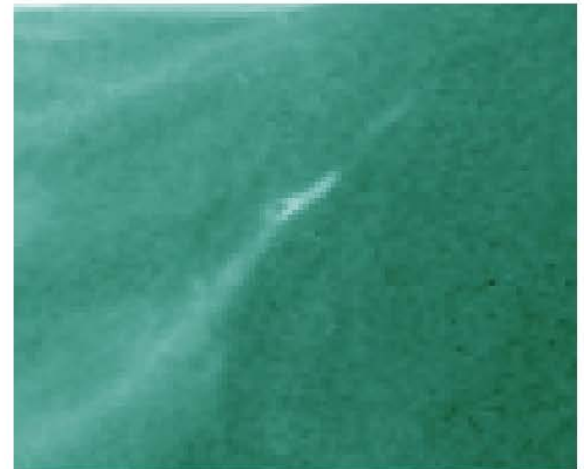
d AIA 193-Å 18:52:07



e Hi-C 193-Å 18:52:08



f AIA 94-Å 18:52:14

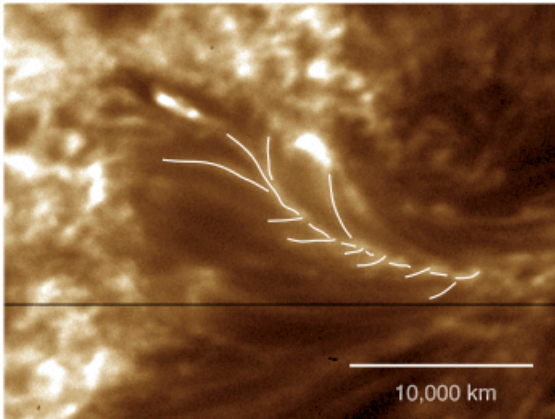


Shortly after the Hi-C flight, a small flare was observed at the field line crossing.

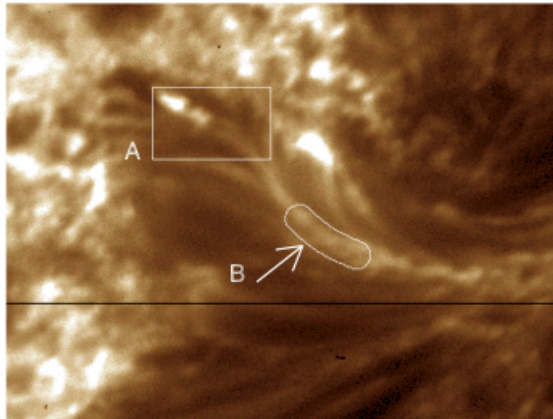
Cirtain et al, 2013, Nature

Braided Loop

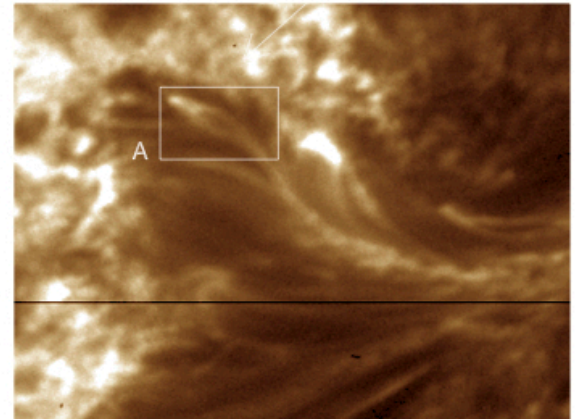
a Hi-C 193-Å: 18:53:28



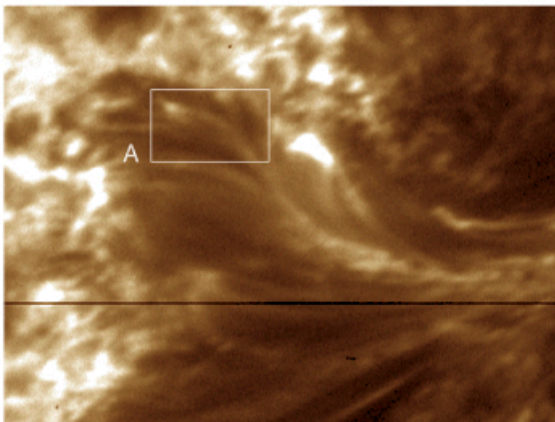
b Hi-C 193-Å: 18:53:45



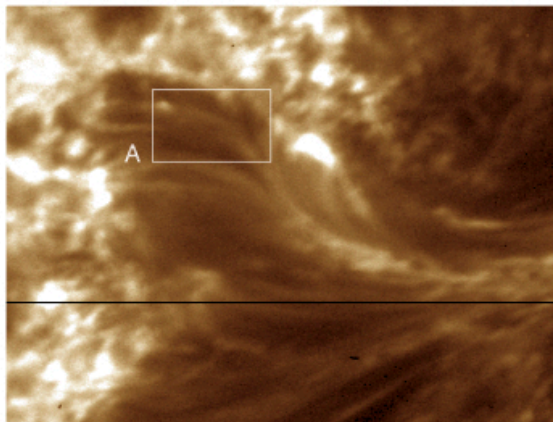
c Hi-C 193-Å: 18:54:13



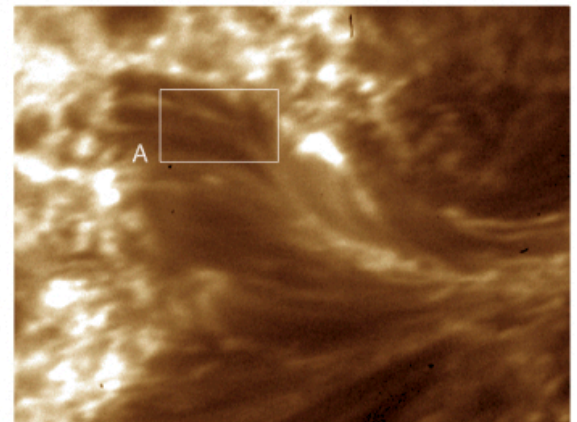
d Hi-C 193-Å: 18:54:41



e Hi-C 193-Å: 18:55:08



f Hi-C 193-Å: 18:55:36

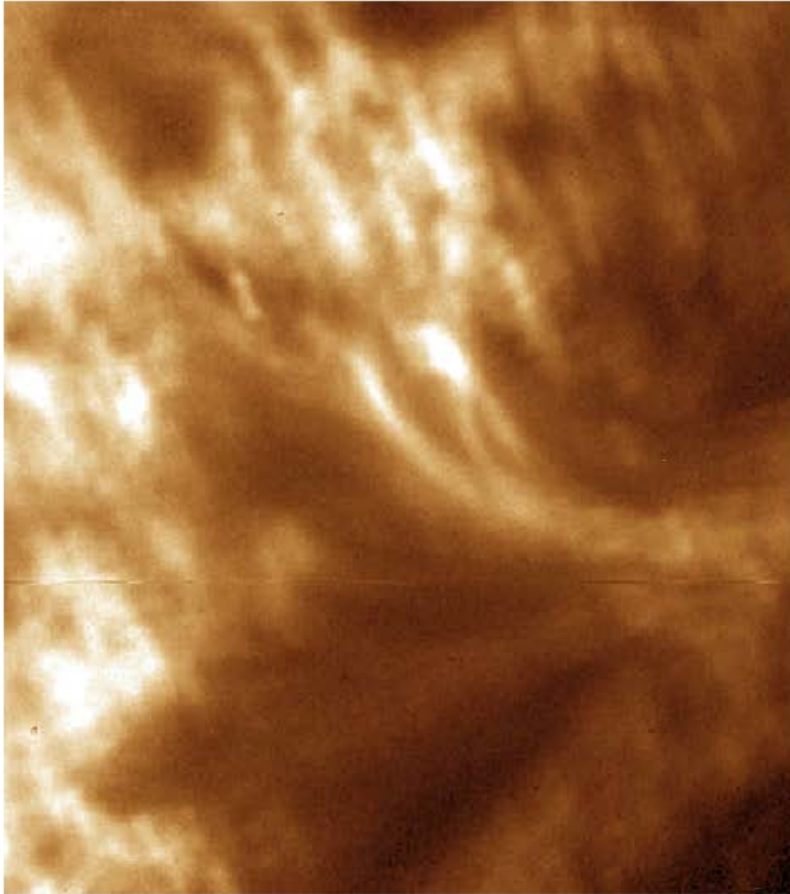


Multiple strands join into this structure. It appears to unwind during Hi-C observations.

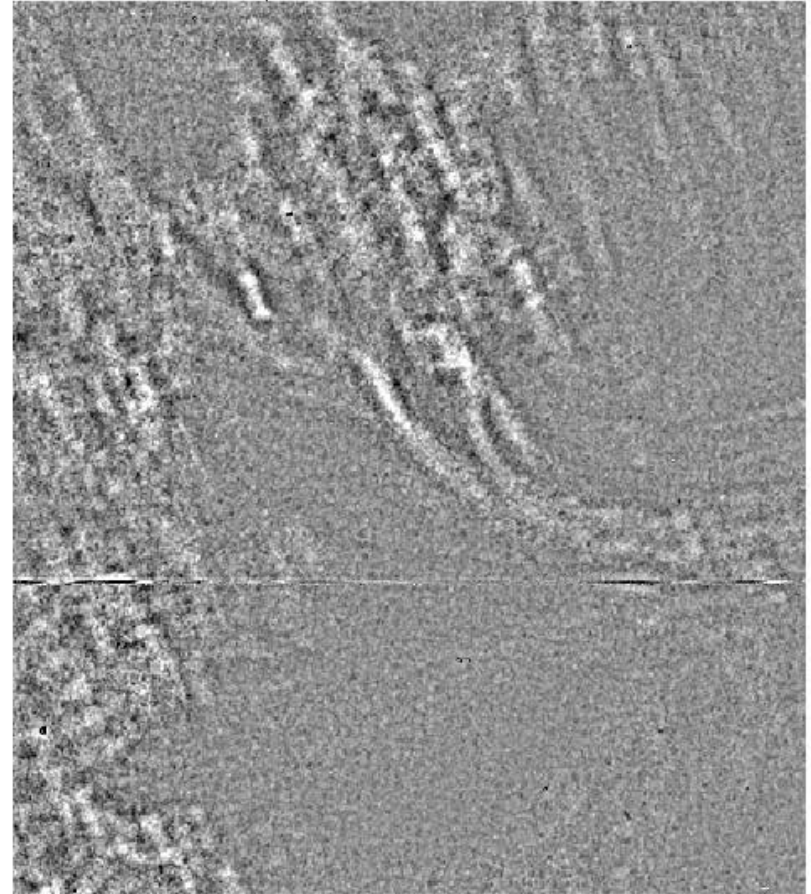
Cirtain et al, 2013, Nature

Braided Loop

a Hi-C 193-Å 18:52:49

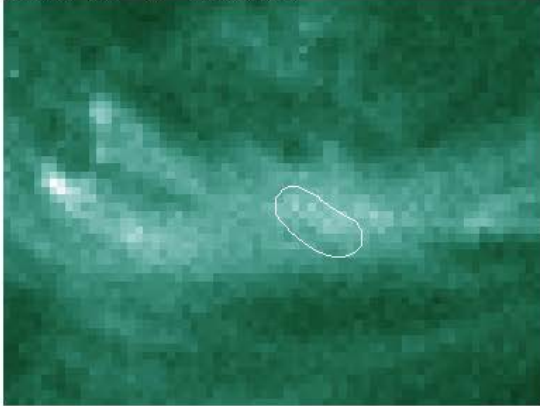


b Hi-C Unsharp Mask

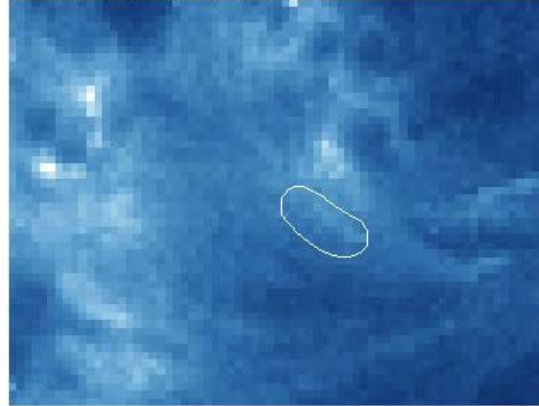


Braided Loop

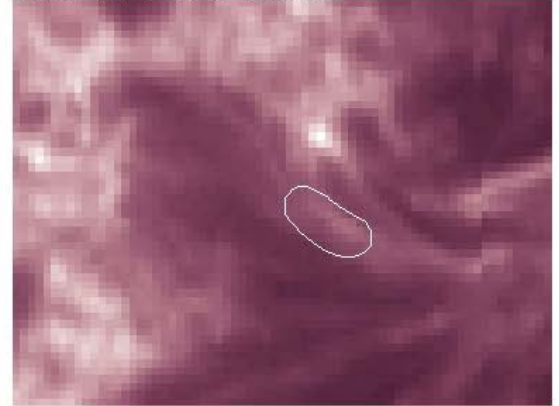
a AIA 94-Å 18:00:01



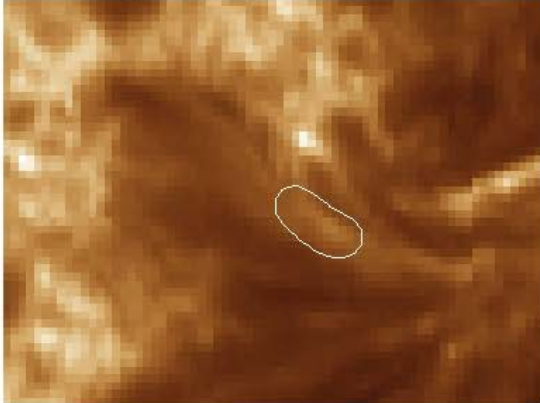
b AIA 335-Å 18:00:02



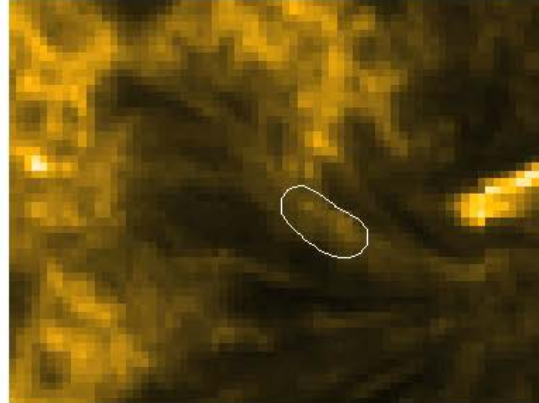
c AIA 211-Å 17:59:59



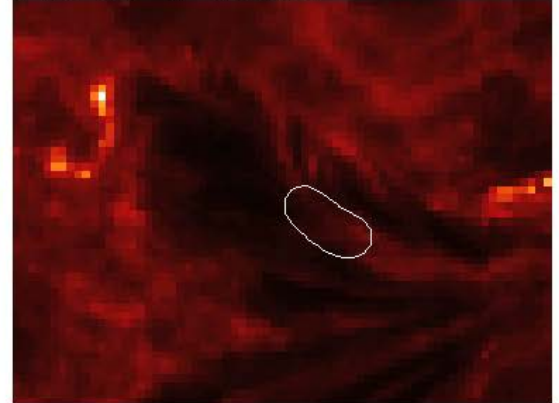
d AIA 193-Å 18:00:06



e AIA 171-Å 17:59:59



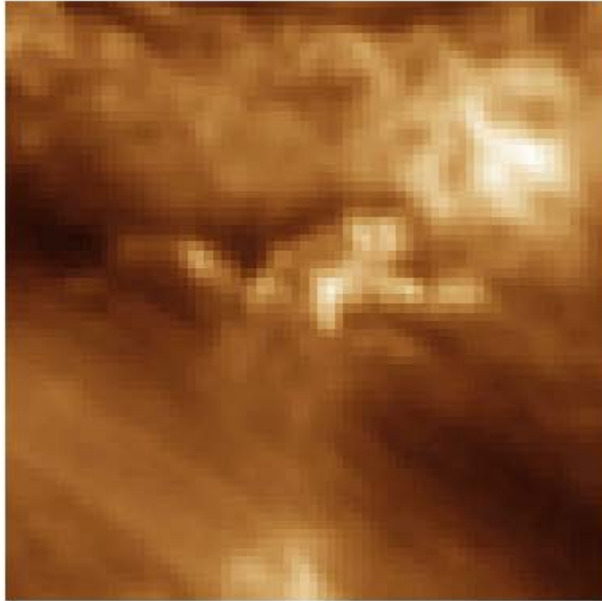
f AIA 304-Å 18:00:07



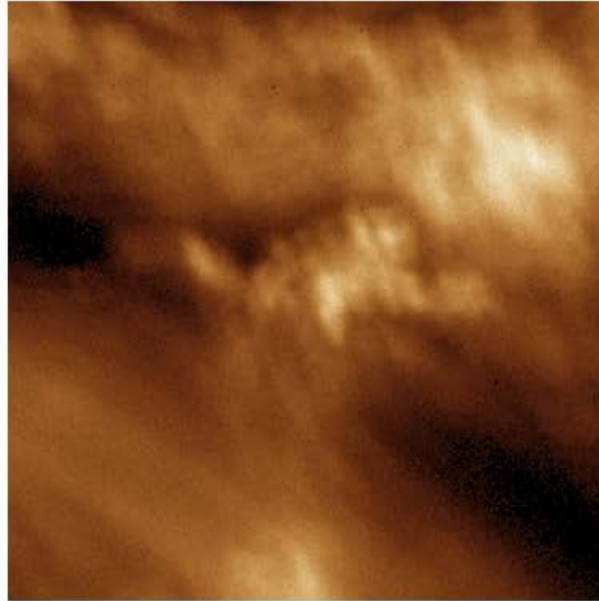
Loop involved in heating event prior to Hi-C flight.

Dynamic Moss

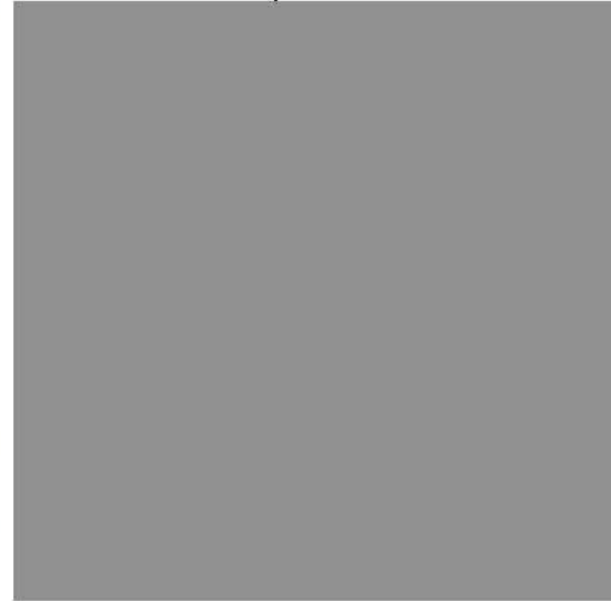
AIA 193 Å : 11-Jul-12 18:52:07.840



Hi-C 193 Å : 11-Jul-12 18:52:07.840

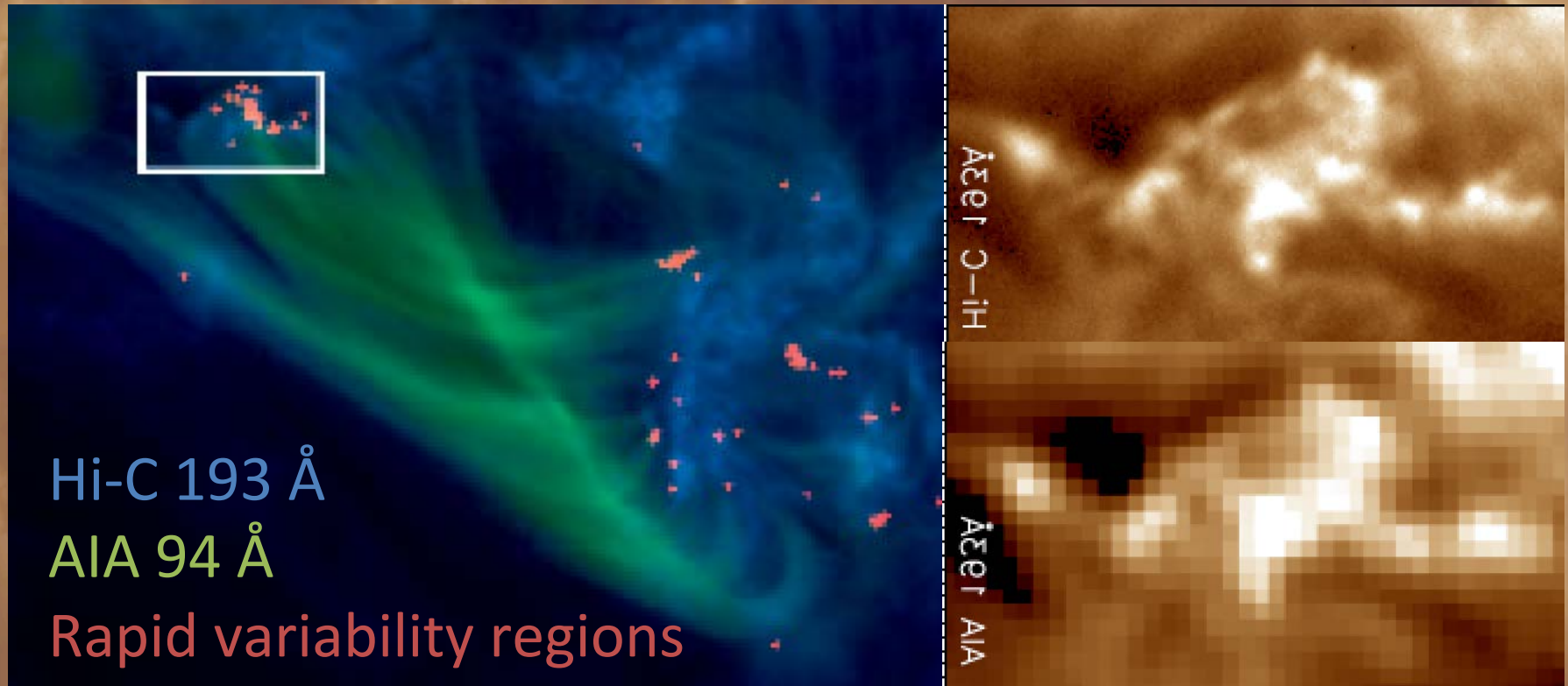


Hi-C 193 Å : Running Difference



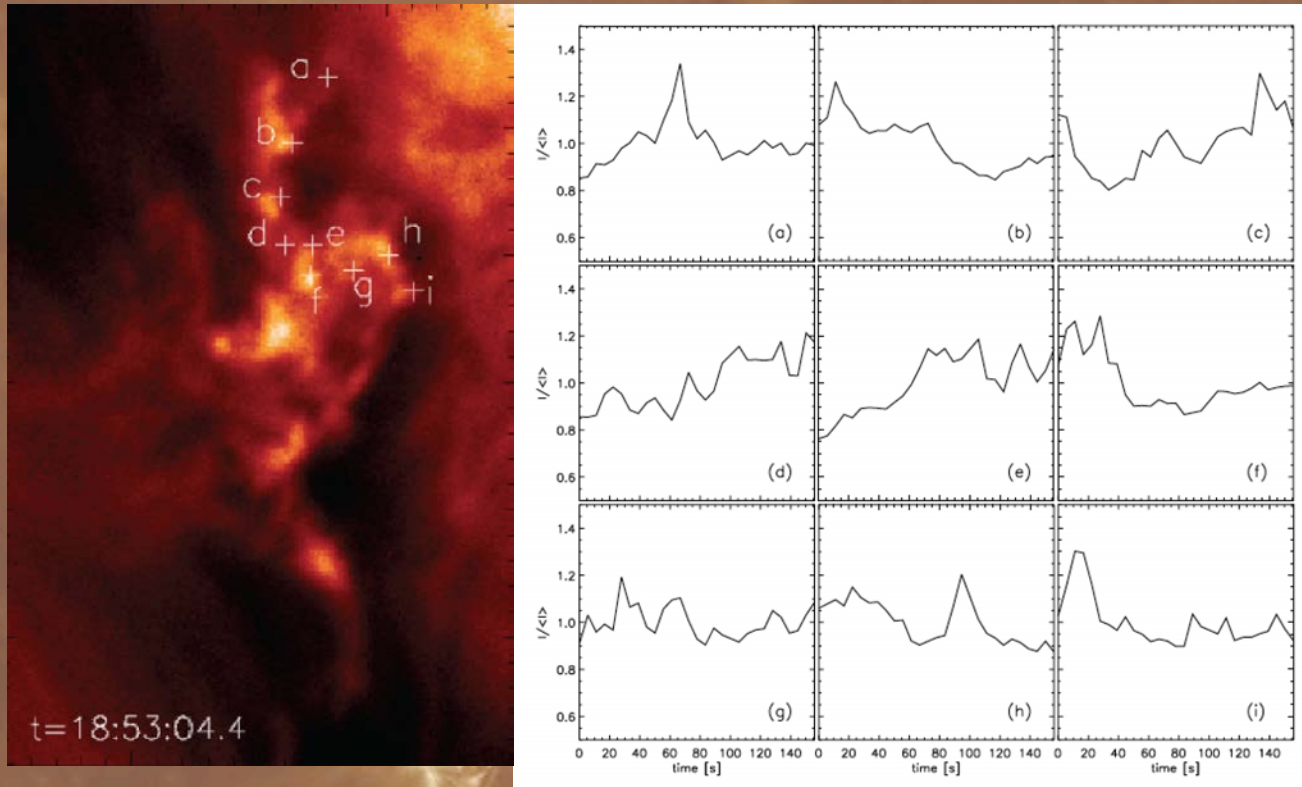
- Hi-C observed a location of highly dynamic moss.

Dynamic Moss



- Dynamic moss occurs at footpoint of high temperature loops.

Dynamic Moss

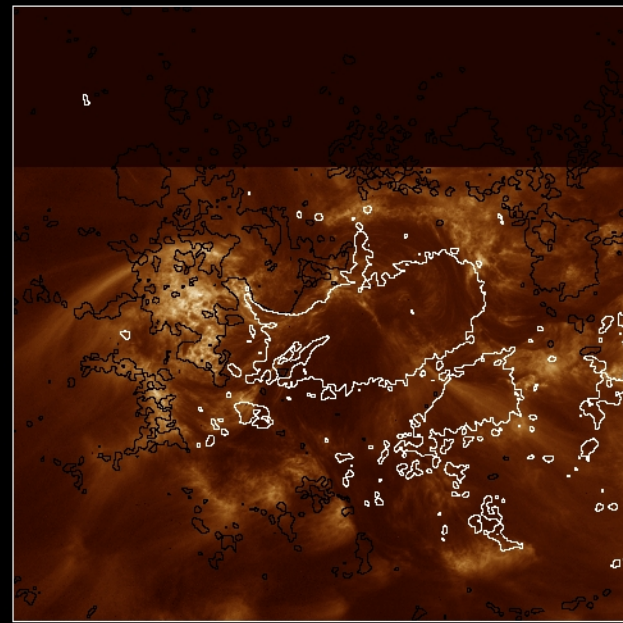
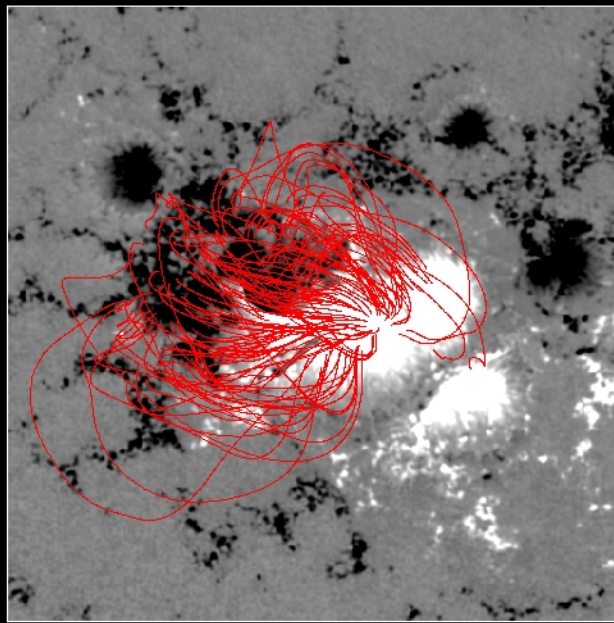
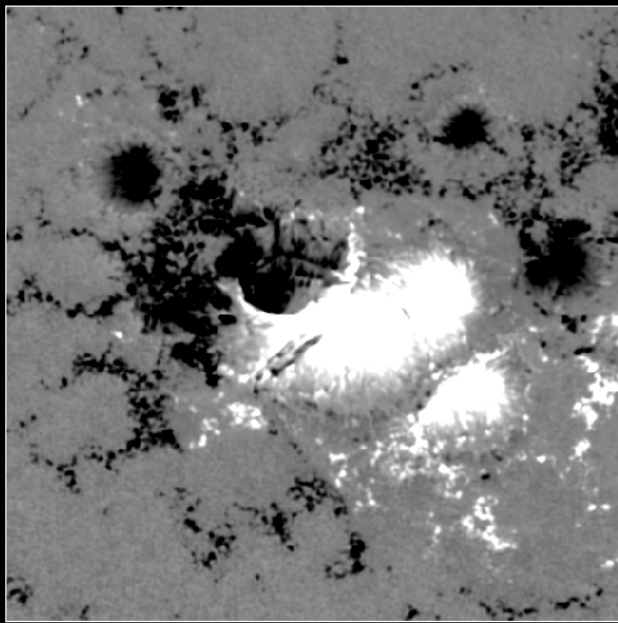


- Events as short as 15 s with increase in intensity on the order of 20-30%.
- Suggestive of footpoint response to coronal reconnection.

Observational evidence for ...

- “Classic nanoflare”
 - Crossed/tangled loops
 - Time dependent brightenings
 - Dynamic moss
- Wave heating / non-classic nanoflare
 - Everything else?

A quick model of Hi-C 1 Active Region



Heating models:

High frequency period
 \sim cooling time/3

Low frequency period \sim
cooling time * 1.5

Heating magnitude
chosen so that
emission measure
weighted average
temperature \sim 4 MK.

